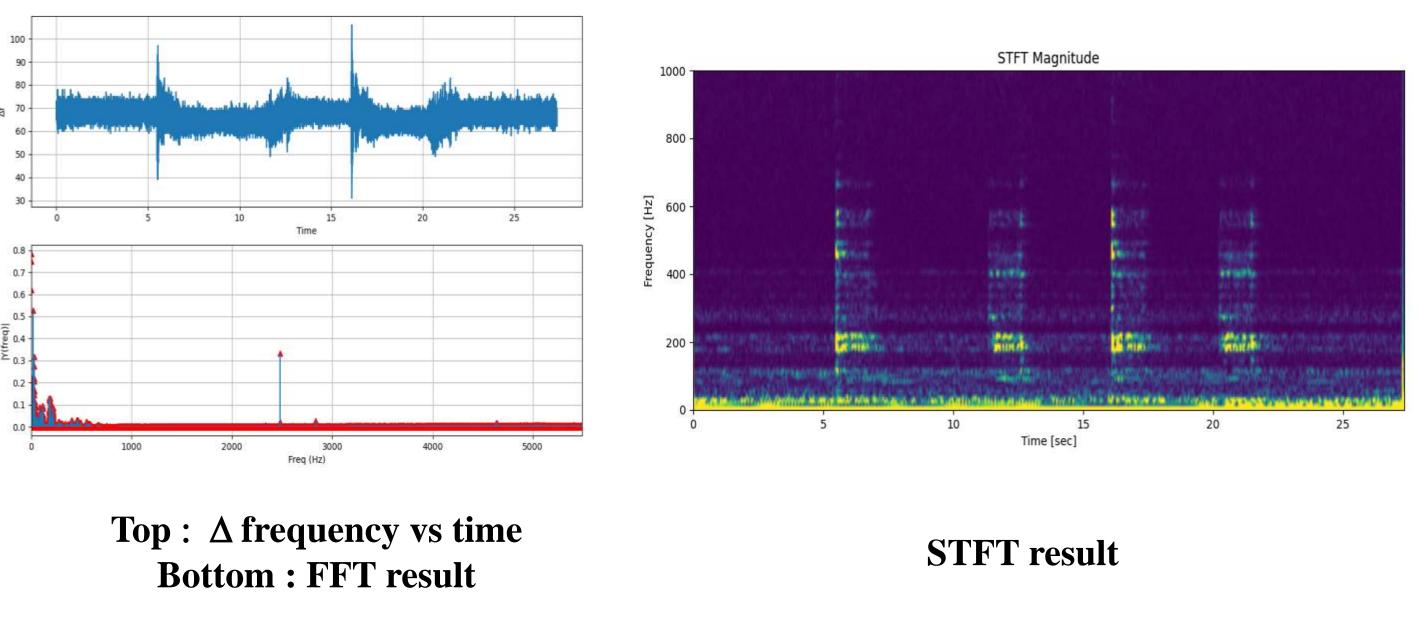
Development of a Cavity Resonance Monitoring System for RAON SCL3

Hyojae Jang, Youngkwon Kim Institute for Rare Isotope Science, Institute for Basic Science, Daejeon, Korea

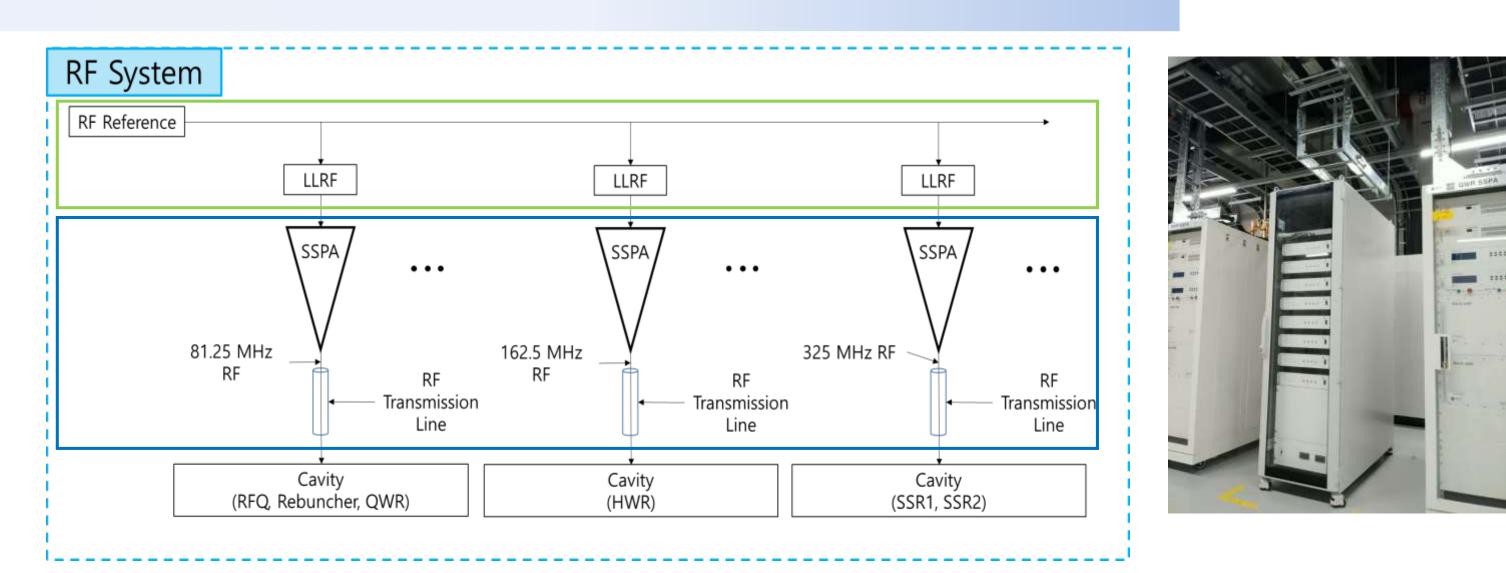
Abstract

Recently the accelerator operation for user beam service are planned in 2024. The SCL3 RF operating frequency are 81.25 MHz and 162.5 MHz. All cavities are controlled independently for the acceleration of the various A/q ions. Because all RAON SCL3 cavities are the superconducting cavities and the planned beam current is not so high, the control bandwidth which is defined by the loaded Q of the power coupler are not so wide and the suppression of the microphonics is one of the important topics for the stable operation. There are a slow cavity resonance frequency drift caused by the long-term LHe pressure drift, fast cavity resonance frequency fluctuation caused by short-term LHe pressure variation or mechanical vibration transferred through the ground. It is required to measure the shifted cavity resonance frequency and to suppress such microphonics which affects the stable RF operation. We developed a cavity resonance monitoring system for RAON SCL3. The shifted cavity resonance frequency is measured and stored by the LLRF. Also a python based tool to transfer and to analyze this data is developed. In this presentation the status and test result of cavity resonance monitoring system for **RAON SCL3 will be described.**

CAVITY RESONANCE MONITORING SYSTEM



RAON RF CONTROL SYSTEM





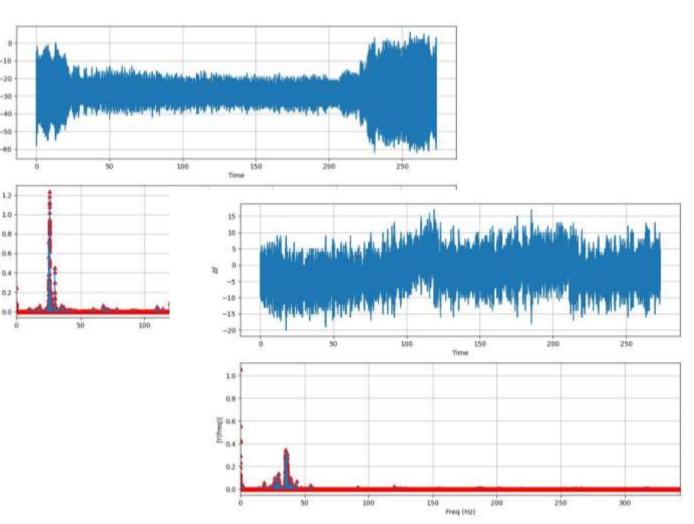
Installed LLRF

80

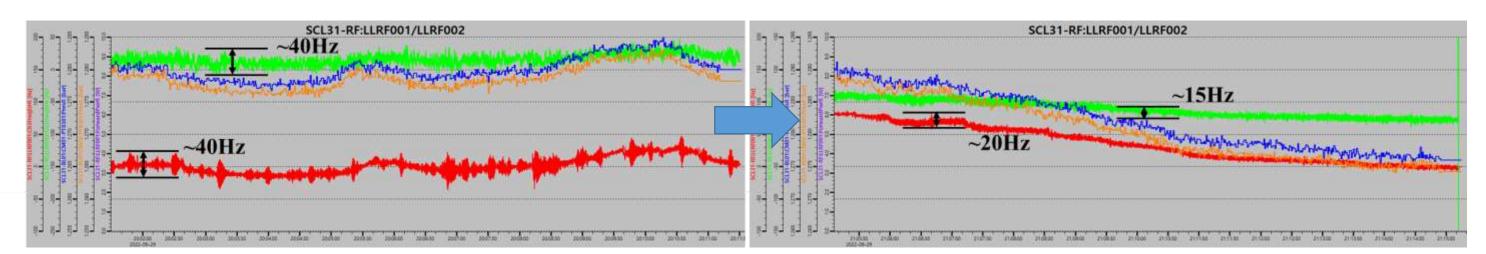
Microphonics occurred in SCL3 were measured by the LLRF and it was used to diagnose and to reduce the it.

Select LLRFs				
Check Uncheck				
SCL31-RF:LLRF001	SCL32-RF:LLRFA01	SCL32-RF:LLRFB01	SCL32-RF:LLRFB27	SCL32-RF:LLRFB53
SCL31-RF:LLRF002	SCL32-RF:LLRFA02	SCL32-RF:LLRFB02	SCL32-RF:LLRFB28	SCL32-RF:LLRFB54
SCL31-RF:LLRF003	SCL32-RF:LLRFA03	SCL32-RF:LLRFB03	SCL32-RF:LLRFB29	SCL32-RF:LLRFB55
SCL31-RF:LLRF004	SCL32-RF:LLRFA04	SCL32-RF:LLRFB04	SCL32-RF:LLRFB30	SCL32-RF:LLRFB56
SCL31-RF:LLRF005	SCL32-RF:LLRFA05	SCL32-RF:LLRFB05	SCL32-RF:LLRFB31	SCL32-RF:LLRFB57
SCL31-RF:LLRF006	SCL32-RF:LLRFA06	SCL32-RF:LLRFB06	SCL32-RF:LLRFB32	SCL32-RF:LLRFB58
SCL31-RF:LLRF007	SCL32-RF:LLRFA07	SCL32-RF:LLRFB07	SCL32-RF:LLRFB33	SCL32-RF:LLRFB59
SCL31-RF:LLRF008	SCL32-RF:LLRFA08	SCL32-RF:LLRFB08	SCL32-RF:LLRFB34	SCL32-RF:LLRFB60
SCL31-RF:LLRF009	SCL32-RF:LLRFA09	SCL32-RF:LLRFB09	SCL32-RF:LLRFB35	SCL32-RF:LLRFB61
SCL31-RF:LLRF010	SCL32-RF:LLRFA10	SCL32-RF:LLRFB10	SCL32-RF:LLRFB36	SCL32-RF:LLRFB62
SCL31-RF:LLRF011	SCL32-RF:LLRFA11	SCL32-RF:LLRFB11	SCL32-RF:LLRFB37	SCL32-RF:LLRFB63
SCL31-RF:LLRF012	SCL32-RF:LLRFA12	SCL32-RF:LLRFB12	SCL32-RF:LLRFB38	SCL32-RF:LLRFB64
SCL31-RF:LLRF013	SCL32-RF:LLRFA13	SCL32-RF:LLRFB13	SCL32-RF:LLRFB39	SCL32-RF:LLRFB65
SCL31-RF:LLRF014	SCL32-RF:LLRFA14	SCL32-RF:LLRFB14	SCL32-RF:LLRFB40	SCL32-RF:LLRFB66
SCL31-RF:LLRF015	SCL32-RF:LLRFA15	SCL32-RF:LLRFB15	SCL32-RF:LLRFB41	SCL32-RF:LLRFB67
SCL31-RF:LLRF016	SCL32-RF:LLRFA16	SCL32-RF:LLRFB16	SCL32-RF:LLRFB42	SCL32-RF:LLRFB68
SCL31-RF:LLRF017	SCL32-RF:LLRFA17	SCL32-RF:LLRFB17	SCL32-RF:LLRFB43	SCL32-RF:LLRFB69
SCL31-RF:LLRF018	SCL32-RF:LLRFA18	SCL32-RF:LLRFB18	SCL32-RF:LLRFB44	SCL32-RF:LLRFB70
SCL31-RF:LLRF019	SCL32-RF:LLRFA19	SCL32-RF:LLRFB19	SCL32-RF:LLRFB45	SCL32-RF:LLRFB71
SCL31-RF:LLRF020	SCL32-RF:LLRFA20	SCL32-RF:LLRFB20	SCL32-RF:LLRFB46	SCL32-RF:LLRFB72
SCL31-RF:LLRF021	SCL32-RF:LLRFA21	SCL32-RF:LLRFB21	SCL32-RF:LLRFB47	SCL32-RF:LLRFB73
SCL31-RF:LLRF022	SCL32-RF:LLRFA22	SCL32-RF:LLRFB22	SCL32-RF:LLRFB48	SCL32-RF:LLRFB74
Save Time :	SCL32-RF:LLRFA23	SCL32-RF:LLRFB23	SCL32-RF:LLRFB49	SCL32-RF:LLRFB75
dfSa∨e	SCL32-RF:LLRFA24	SCL32-RF:LLRFB24	SCL32-RF:LLRFB50	SCL32-RF:LLRFB76
dfGet	SCL32-RF:LLRFA25	SCL32-RF:LLRFB25	SCL32-RF:LLRFB51	

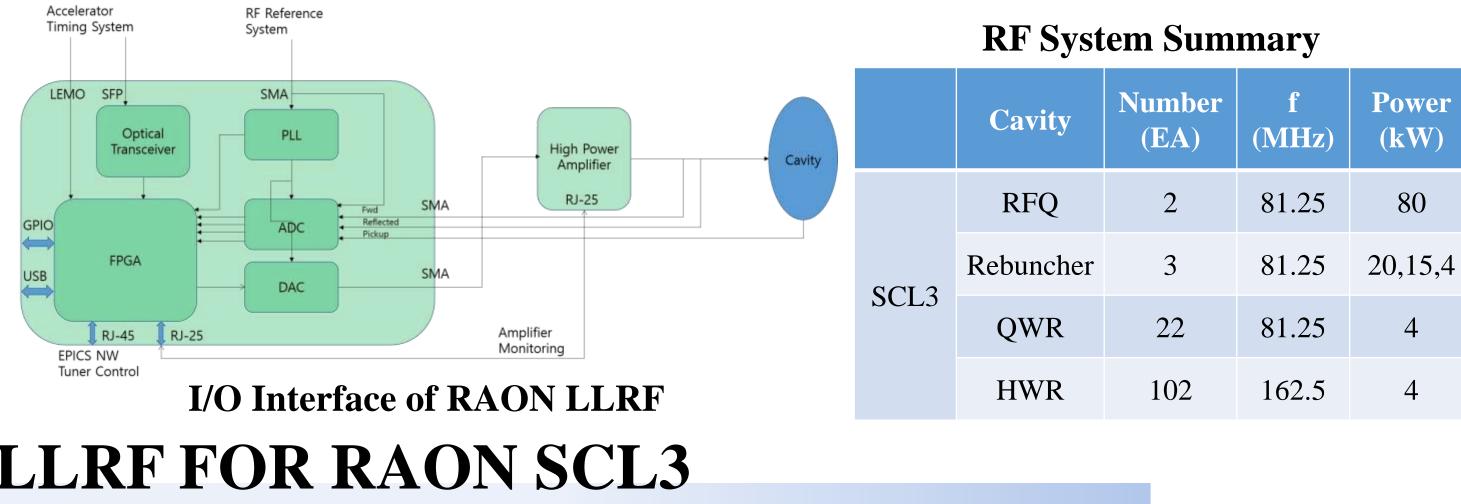
Tool for frequency error measurement



Example of measured cavity microphonics Left : HWR cavity, Right : QWR cavity



For the RF control of 1 cavity, 1 SSPA(Solid State Power Amplifier / 1 LLRF (Low Level RF) pair is planned at RAON accelerator.





Item	Spec
RF Input	4
RF Output	1
RF ADC	AD9653(16 bit, 4 ch, LVSD)
SoC	Xilinx Zynq Ultrascale ZU9EG
EPICS IOC	In Arm core of Zynq
Clock Gen	LMK04828 PLL

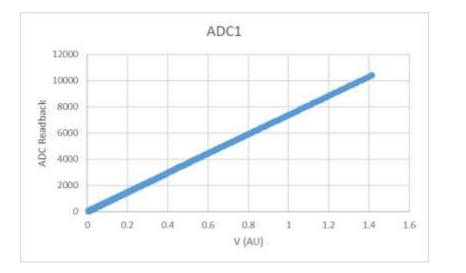
- With PLL circuit, the sampling of ADC, DAC/clocking of FPGA can be changed easily.
- One hardware can support any cavity in SCL3 (low energy, 81.25 and 162.5 MHz) and SCL2 (high energy, 325 MHz) Generator-Driven mode and Self-Excited Loop algorithm have been implemented and being tested.

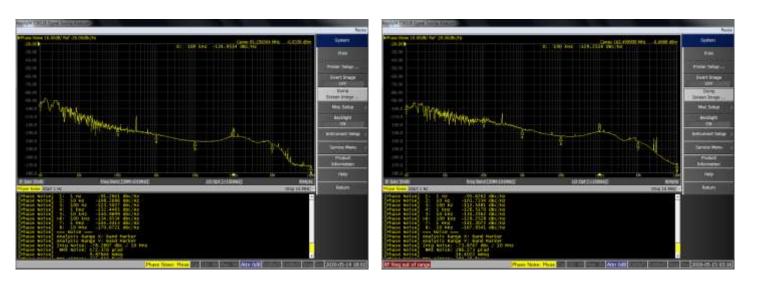
Microphonics mitigation (Left : before, Right : after)

- For the operation of RF system, several tools were developed.
- For superconducting cavity, the measurement of microphonics (caused by LHe pressure fluctuation, external vibration, etc.) is important to suppress it.
- The frequency error measurement logic implemented in LLRF FPGA calculates the current resonant frequency of the cavity at sampling rate(about 10 kHz).
- Measured data are stored temporarily in DRAM of LLRF and saved as a file.
- All control (measurement trigger, duration, status, etc.) can be done by EPICS and a tool to operate this was developed by Python code.
- This tool was one of the important key for the suppression of the microphonics at RAON SCL3 accelerator and contributed for the success of the first beam commissioning and accelerator operation since 2023.

SUMMARY

- FPGA-based LLRF has been developed and installed at RAON accelerator.
- Implementation of Digital SEL mode and Generator Driven Mode algorithm and their verification test have been performed at RAON SRF TF.
- Some functions for the SRF test (microphonics measurement, etc.) were developed and implemented and it was useful for the microphonics mitigation.
- Tool to operate this resonance monitoring system was developed and it is based on





ADC Linearity Test $(P_{in} = +3 \sim -40 \text{ dBm})$

DAC Test @81.25 MHz, 162.5 MHz **RMS Jitter < 0.29 mdeg**

Python code.

Developed cavity resonance monitoring system was used for the diagnostic of microphonics and it contributed for the beam commissioning of RAON accelerator.

ACKNOWLEDGEMENT

This work was supported by the Institute for Basic Science(IBS-I001-D1)



